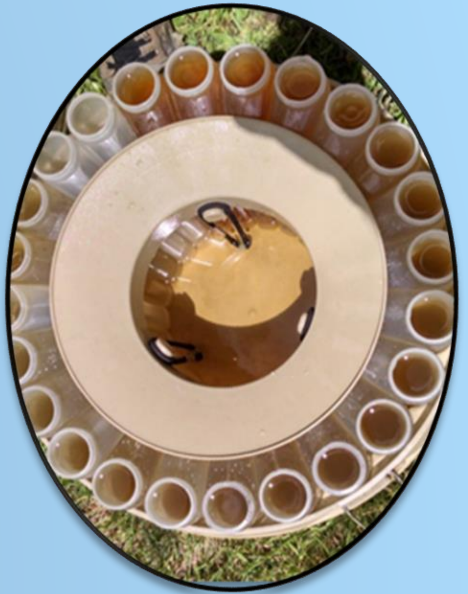
Iron-Enhanced Sand Filter (IESF) Performance for Phosphorus, Metals, and Trace Organic Contaminants: Overview of Three Field Studies



ASCE – EWRI World Congress| June 7th, 2018

David J. Fairbairn, PhD | Research Scientist | Minnesota Pollution Control Agency

MINNESOTA POLLUTION CONTROL AGENCY

Iron-Enhanced Sand Filters – 10,000 ft Overview

What IESFs Are

- Filtration BMP: Sand filter + Fe
- Oxidized Fe removes dissolved constituents, e.g., phosphate
- Primary IESF treatment mechanisms: filtration & sorption

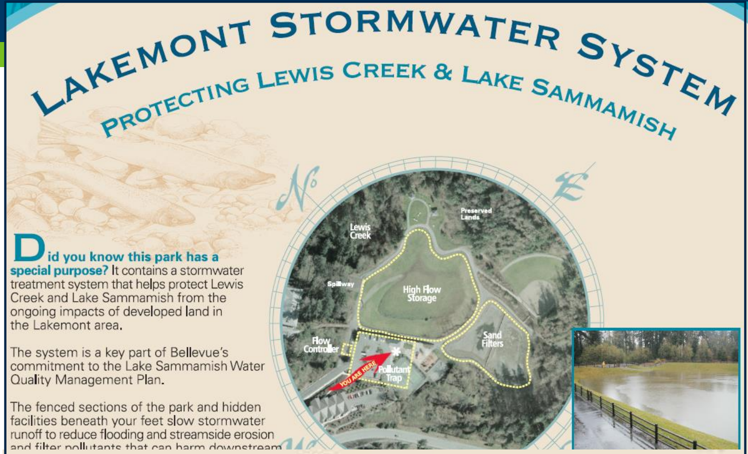
Why we care: Many stakeholders, including MPCA

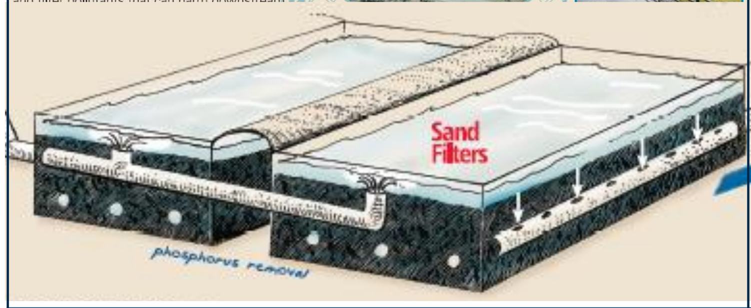
- **MPCA: Mission & activities**
  - Monitor environmental quality,
  - Provide technical & financial assistance
  - Enforce environmental regulations
- **General Reasons:** TMDLs, stormwater regs, water & stormwater mgmt
- **Because we should!**

IESF History - Stormwater

- **1980s:** WA - Lab tests for treating dissolved phosphorus in stormwater
- **1990s:** Lakemont Washington Filtration Facility[1]
- **2009:** Maplewood Mall, MN: Barr Engineering for Ramsey Washington Metro Watershed District[2]
- **UMN/SAFL:** Completed several lab & field studies, advises, greatly helped expand IESF use[3,4]
- **Recent: Design & Implementation Developments**
  - ✓ Successes & Failures
  - ✓ Growing Numbers
- **MN Guidance**
  - ✓ MN Stormwater Manual (MPCA)
  - ✓ MIDS Calculator (MPCA)

[1] King County, 1999
[2] City of Minneapolis, 2015
[3] Erickson et al., 2012
[4] Erickson et al., 2015





IESFs – MN Background (Recent History)

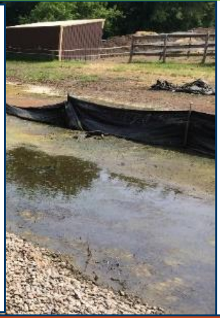
WIKI

Minnesota Stormwater Manual

Search | Search Help | Log in

Design criteria for iron enhanced sand filter

Page Contents



RCWD

RICE CREEK WATERSHED DISTRICT

Search

Home | About the RCWD | Press Room | Contact Us

- Projects
- Grant Opportunities
- Get Involved
- Water Quality
- Public Drainage
- Rules & Permitting
- Reports & Plans
- Rice Creek Water Trail
- Local Water Planning

Golden Lake Iron-Enhanced Sand Filter

The Rice Creek Watershed District (RCWD) partnered with the Anoka Conservation District (ACD) and the City of Blaine to install a new iron-enhanced sand filter (IESF) to treat polluted rainwater before it reaches Golden Lake. The ACD was awarded a Clean Water Fund grant, from the Clean Water, Land, and Legacy Amendment, in the amount of $88,590 for the project with an additional $40,615 in local matching funds provided by the RCWD and $24,440 from the City of Blaine. Construction will take place in August 2015.

Golden Lake is an impaired lake within a fully developed area of the Twin Cities, surrounded by residential land use, and the focal point of a city park. The IESF will achieve 11% of the phosphorus reduction required for Golden Lake to meet State water quality standards, as identified in the TMDL study. In addition, the IESF was the most cost-effective

project identified in the Golden Lake Subwatershed Stormwater Retrofit Analysis.

The IESF will be retrofitted to an existing stormwater pond within Blaine's Centennial Green Park, which discharges to Anoka County Ditch 53-62 and then Golden Lake. The IESF will provide treatment of dissolved phosphorus (21 lbs/yr), which is otherwise predominantly untreated and comprises approximately 44% of the total phosphorus pool in stormwater runoff.

CLEAN WATER LAND & LEGACY AMENDMENT

This project provides a highly cost effective BMP for reducing the negative impacts of stormwater runoff on water quality within Golden Lake, one of two strategies identified in the approved TMDL that will have the most impact. Collaboration among the Anoka Conservation District, the City of Blaine, and the Rice Creek Watershed District reflects the regional significance and importance of this project.

Journal of Environmental Engineering / Volume 144 Issue 1 - January 2018

Case Studies

Monitoring and Maintenance of Phosphate Adsorbing Filters

Andrew J. Erickson; Peter T. Weiss, M.ASCE; and John S. Gulliver, F.ASCE

FULL TEXT | DOWNLOAD | TOOLS | SHARE

Abstract

Field installations of two iron-enhanced sand filters (IESFs), designed to remove phosphate and particulates from stormwater runoff, were monitored and maintained for 1–3 years. One application, a traditional IESF in an agricultural watershed, retained over 64% of the influent phosphate load, whereas the second, a

IESFs - Design Tidbits

Iron Content[1]

- **5-8% Fe (w/w)** of Fe-sand mixture (Erickson et al., 2012)
  - Assumes high surface area, ~90% elemental Fe filings
  - Lifespan & performance affected by variable Fe composition

Hydraulics[1]

- **Clogging = greatest O&M challenge**
  - Poor drainage -> fouling or Fe release
- **2'-6' head** often recommended
- Filter should **draw down** within 48h of storm completion
  - This is typical MN guidance, esp. important for IESFs
- **Minimize tailwater** to allow dryout
- **Underdrain** should be present, vent to atmosphere, be above ds high-water level

[1] MN Stormwater Manual, 2017

IESFs - Design Tidbits

Vegetation

- IESFs mainly effect filtration & sorption, not volume reduction
  - Vegetation isn't necessary, may impair function

Iron Depletion

- Potential signs that P binding capacity is depleted:[1,2]
  - Ouflow TP consistently > 60-70 ppb
  - TP:Fe ratios in media > 5 mg P/ 1g Fe
    - During lifespan, several forms of P, other constituents will bind to Fe
    - Thus, TP:Fe analysis only yields approximate P binding capacity.

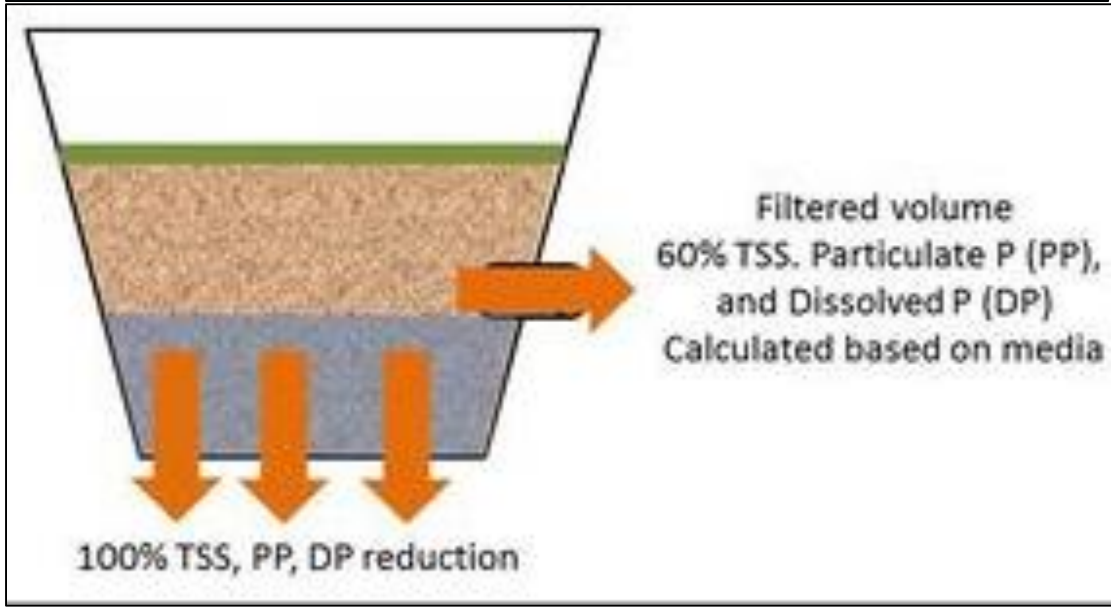
[1] Erickson et al., 2007

[2] Erickson et al., 2012

IESFs – Pros of High-Functioning Systems

Good:

- Removal of colloidal & dissolved contaminants
- Pollutant removal rates
- Retrofit for ponds, other BMPs
- For nutrient impairments
- Alternative when infiltration is infeasible



IESFs – Current Gaps & Limitations

Considerations:

- Relatively unexplored tech, limited P performance history or research
- May be most suited to urban areas, moderate sediment loads
- Lifespan limited by clogging, Fe loss, maintenance cycles
- Vegetative buildup/decomposition may reduce DO -> affect Fe -> fouling
- Head needed for treatment, drawdown
- Tailwater constraints may restrict siting
- Bed material will require disposal when depleted
- Limited water quantity control

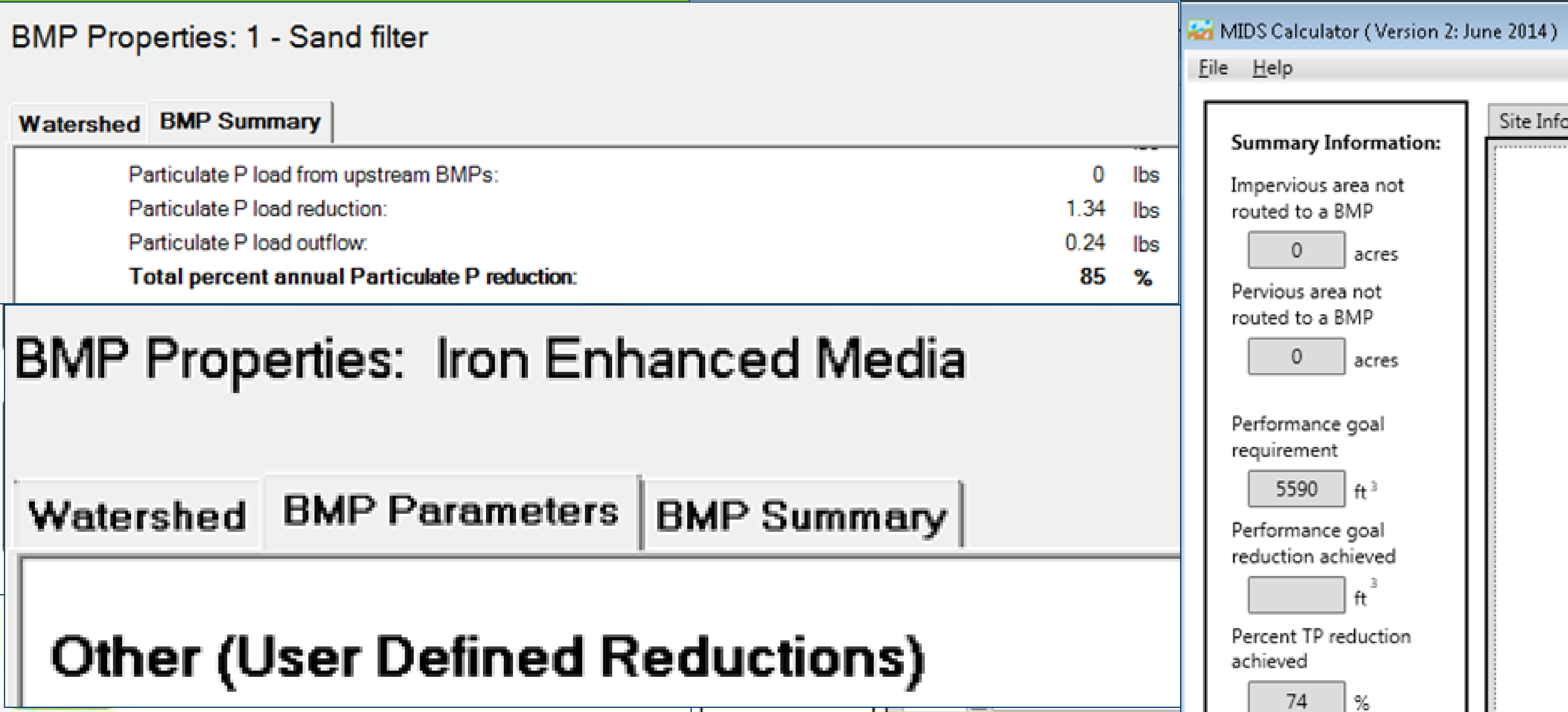
IESFs - Crediting Approaches

Stormwater credits are tools for:

- Local authorities interested in incentivizing natural preservation, reducing urban runoff pollution
- Complying with permits, including antidegradation
- Meeting MIDS performance goal
- Meeting or complying with WQ objectives, including TMDL wasteload allocations (WLAs)

MPCA-recommended IESF credits[1]								
BMP	**TSS**	**TP**	**PP**	**DP**	**TN**	**Metals**	**Bact.**	**Hydrocarbons**
Pond	85	50	91	0	30	70	60	80
Sand filter	85	50	91	0	35	50	80	80
IESF	85	77	91	60	35	50	80	80
Pond+IESF (est)	98	~85	99	60	55	85	92	96

IESFs - Crediting Approaches – MIDS Calculator



IESFs: Research & Monitoring Background

- **Promising DP performance in lab (>80%)[1]**
- **Varying results in field[2] & local experiences**
- **Desire among MN regulators & practitioners**
  - Get ahead of potential issues
  - Understand successes and failures
  - Optimize designs
  - Support implementation

[1] Erickson et al., 2012

[2] Erickson et al., 2015

IESFs: MPCA Research & Monitoring, 2015-Present

c

- **Goal:** Collect multi-year field data from multiple IESFs to assess overall performance & influences
  - **Engage in partnerships** to ensure applicability, gain value
- **Design**
  - Field Monitoring of Existing IESFs
  - Hydrology
  - Chemistry – TP/DP, others as feasible, CECs
- **Local Partners & Projects**
  - City of Minneapolis, Mpls Board of Parks & Rec – 3 sites
  - Ramsey Washington Metro Watershed District – 2-ish sites
  - City of Prior Lake – 3 sites
  - Capitol Region Watershed District (CEC project) – 2 sites

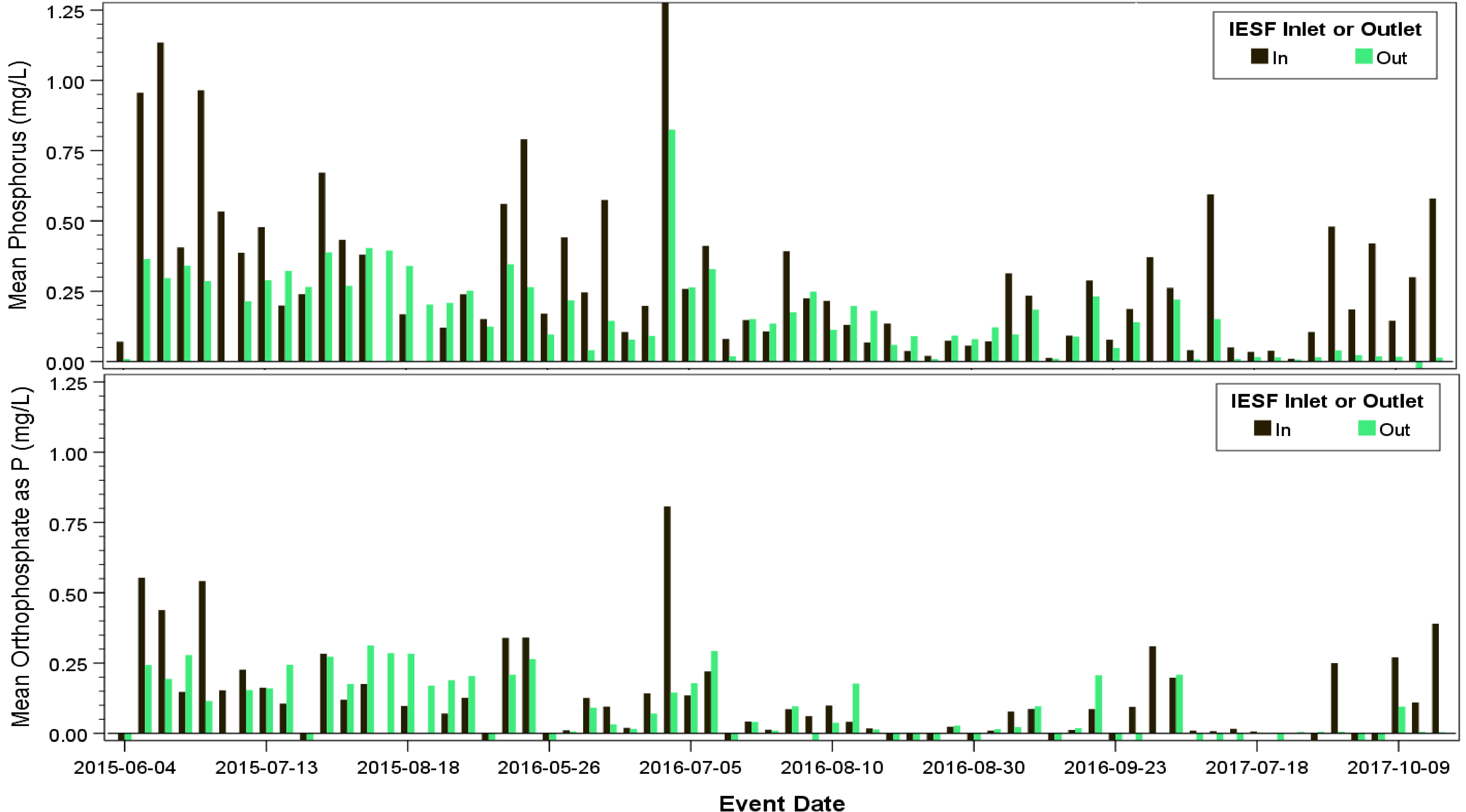
Projects Status To Date

IESF Studies	Minneapolis	RWMWD	Prior Lake	CRWD – special study
Sampling Status	Complete	June 2018	June 2018 (*data not reported here*)	Complete
Sampling Period	2015-2016	2016-Present	2017-Present	2016
# of IESFs	2	2*	2, + 1 control	2
# of Sampling points	4	7	8	4
# of Events (approx.)	50	40	20	6
# of Samples	345	150	300 (est.)	40
Analytes of Interest	TP, DP, Fe, TSS	TP, DP, metals, Cl, TSS	TP, DP, metals, TSS	400 CECs, 50 bioassays, etc.
IESF Notes	In-line w/small res. storm sewer	Parking lot	3 stormwater ponds, 2 w/IESF bench filters	2 ponds with IESF bench filters
Study notes	All projects include watershed land use assessments, IESF details, precip, flow/level monitoring – In progress			

Preliminary Chemistry Results Analysis

	TSS	TP	Ortho-PO_4	TDP	TKN	NO_3 N	Cl	Fe Diss.	Pb Diss.	Zn Tot.
	mg/L	ug/L	ug/L	ug/L	mg/L	mg/L	mg/L	ug/L	ug/L	ug/L
# of Discrete Location-Events	135	212	164	214	44	42	58	119	34	34
Detection Freq. (%)	100	100	72	82	32	93	66	98	53	76
Median Conc.	14	180	42	110	<RL	0.27	1.3	414	0.56	12
Max. Conc.	1300	3400	1000	1400	5.7	1.4	310	8300	3.2	85

Notes: *Not all sites represented; Mass loading analysis is ongoing*



IESF Inlet or Outlet
In
Out
Mean Phosphorus (mg/L)
1.25
1.00
0.75
0.50
0.25
0.00
IESF Inlet or Outlet
In
Out
Mean Orthophosphate as P (mg/L)
1.25
1.00
0.75
0.50
0.25
0.00
2015-06-04
2015-07-13
2015-08-18
2016-05-26
2016-07-05
2016-08-10
2016-08-30
2016-09-23
2017-07-18
2017-10-09
Event Date

Phosphorus and TSS – IESF Inlets vs. Outlets

Non-Parametric Mixed Linear Effect Model:

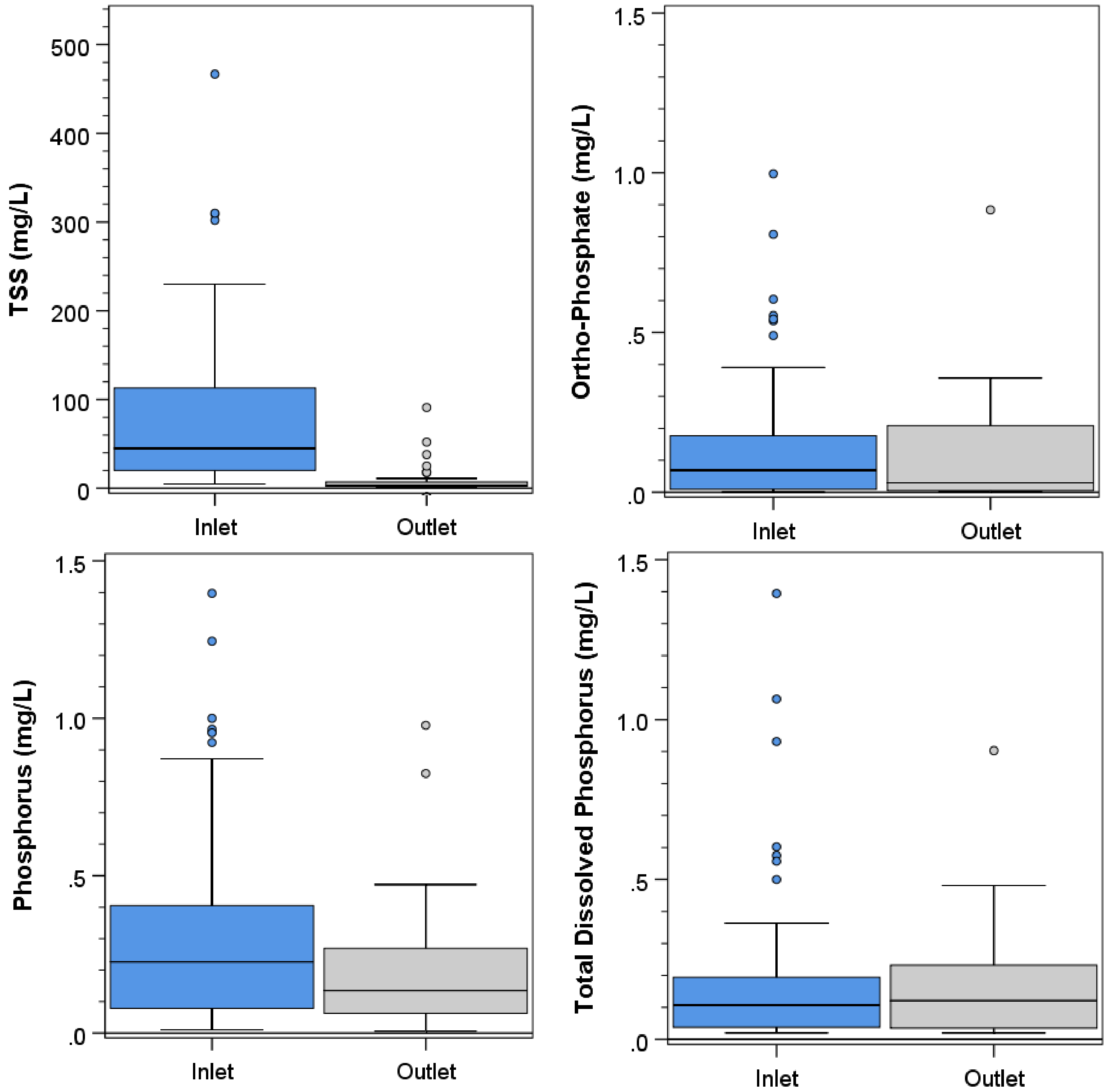
- Significant differences in IESF inlet vs. IESF outlet concentrations of TP, OP, TSS
- Respective p-values: <0.001, 0.010)

TDP Notes:

- **QA questions for** some TDP data
- Currently, TDP results not directly comparable to OP & TP as fewer TDP samples were analyzed

General Stats Notes:

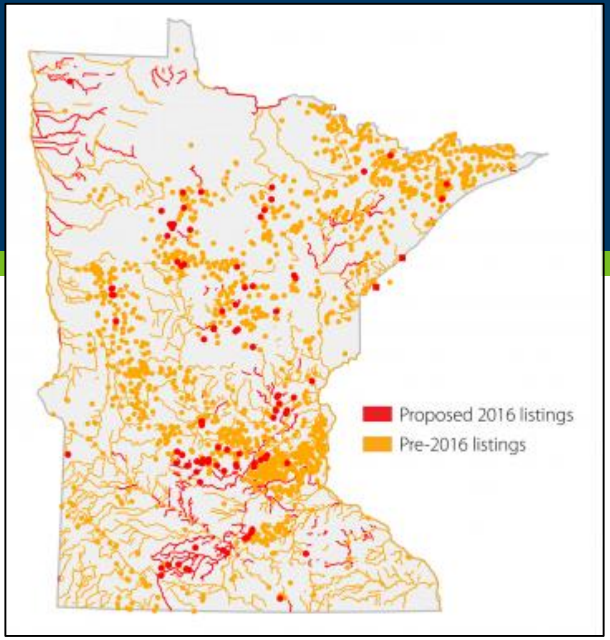
- These are **preliminary** results
- Further analysis to focus on watershed & BMP factors, hydrology, mass loads



Preliminary Chemistry Results Analysis

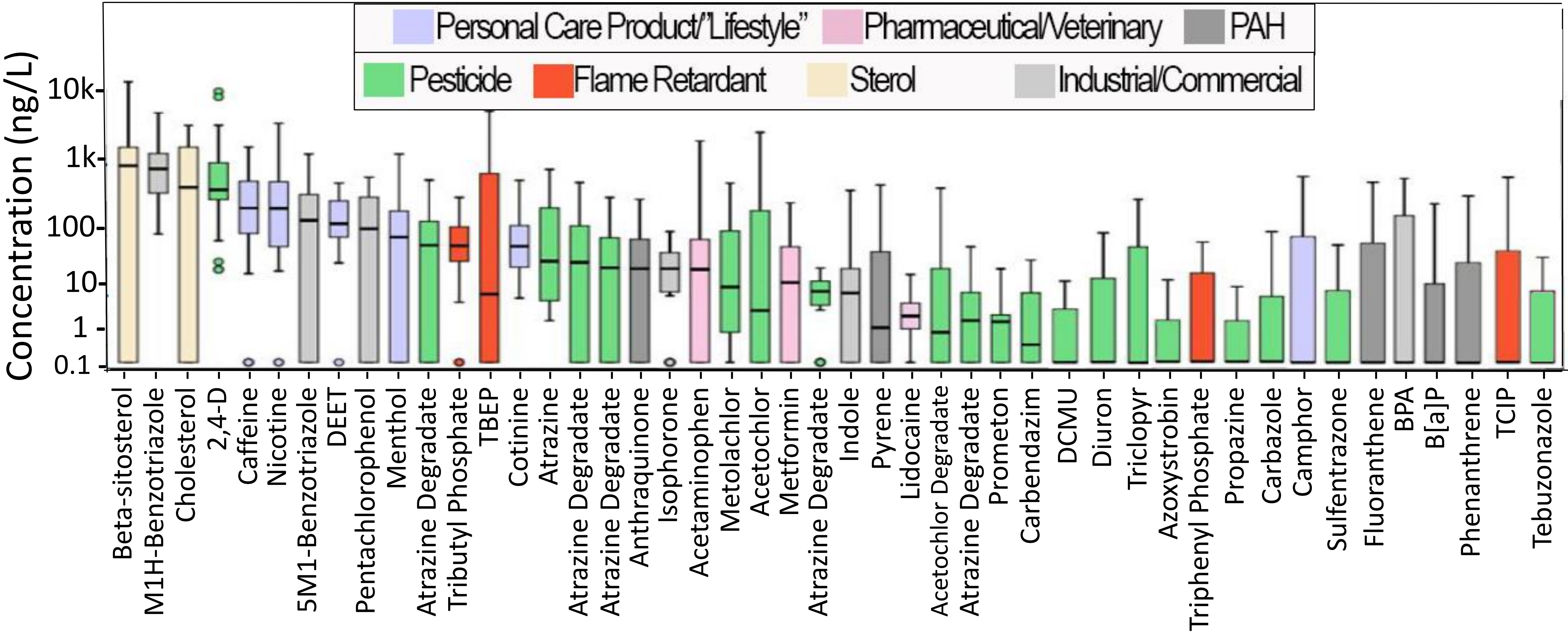
	TSS	TP	Ortho-PO_4	TDP	TKN	NO_3 N	Cl	Fe Diss.	Pb Diss.	Zn Tot.
	mg/L	ug/L	ug/L	ug/L	mg/L	mg/L	mg/L	ug/L	ug/L	ug/L
# Discrete Events	135	212	164	214	44	42	58	119	34	34
Detection Freq. (%)	100	100	72	82	32	93	66	98	53	76
Median Conc.	14	180	42	110	<RL	0.27	1.3	414	0.56	12
Median - Inlets	45	230	69	110	<RL	0.16	1.2	720	0.29	33
Median - Outlets	3.0	140	29	120	<RL	0.28	1.4	210	<RL	3.6
Max. Conc.	1300	3400	1000	1400	5.7	1.4	310	8300	3.2	85

IESFs: Why Should We Care?

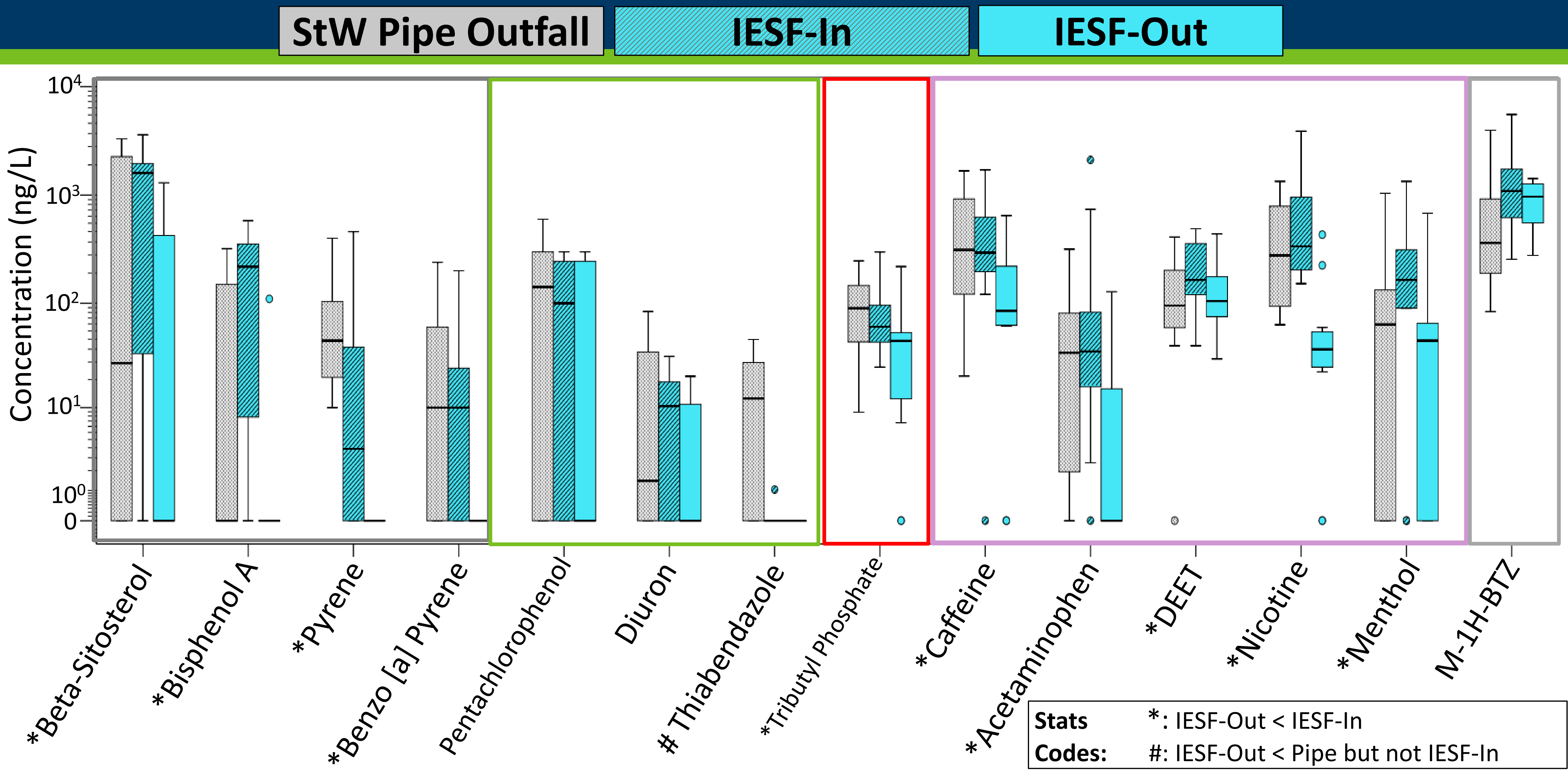


- Many urban waters are nutrient-impaired
- Can be hard to meet TMDL nutrient wasteload allocations for stormwater without removing dissolved P
- We need a good toolbox. This includes:
  - Understanding various influences on performance & longevity
    - Configurations, media composition, other amendments
    - Biogeochemistry – macro and micro
    - Contributing drainage
    - Best practices for routine and non-routine maintenance

CECs that were detected in >25% of stormwater samples



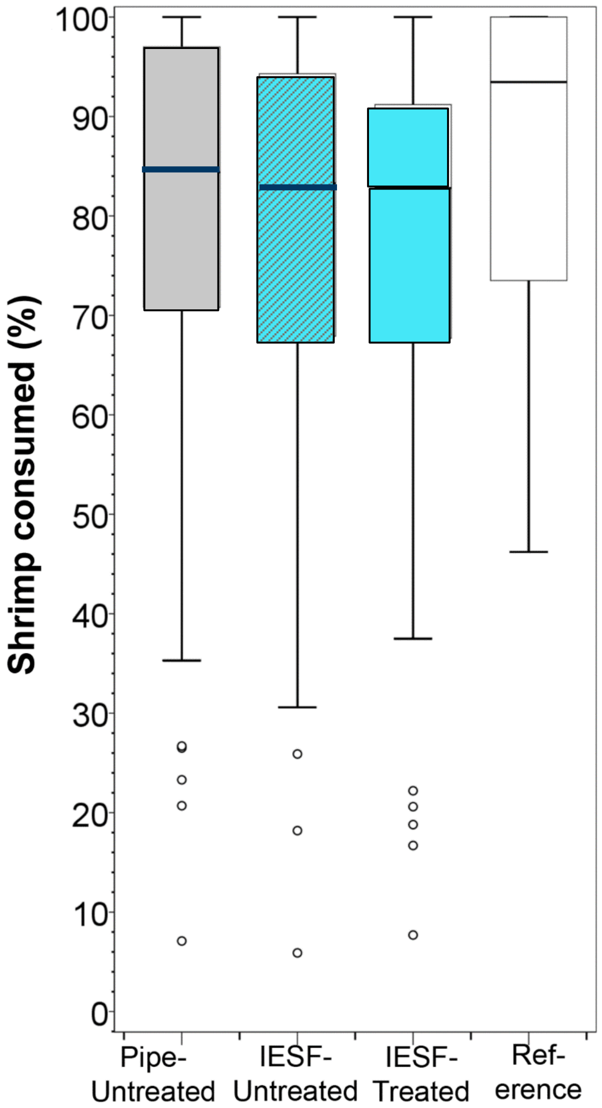
CEC Concentrations By Site Type

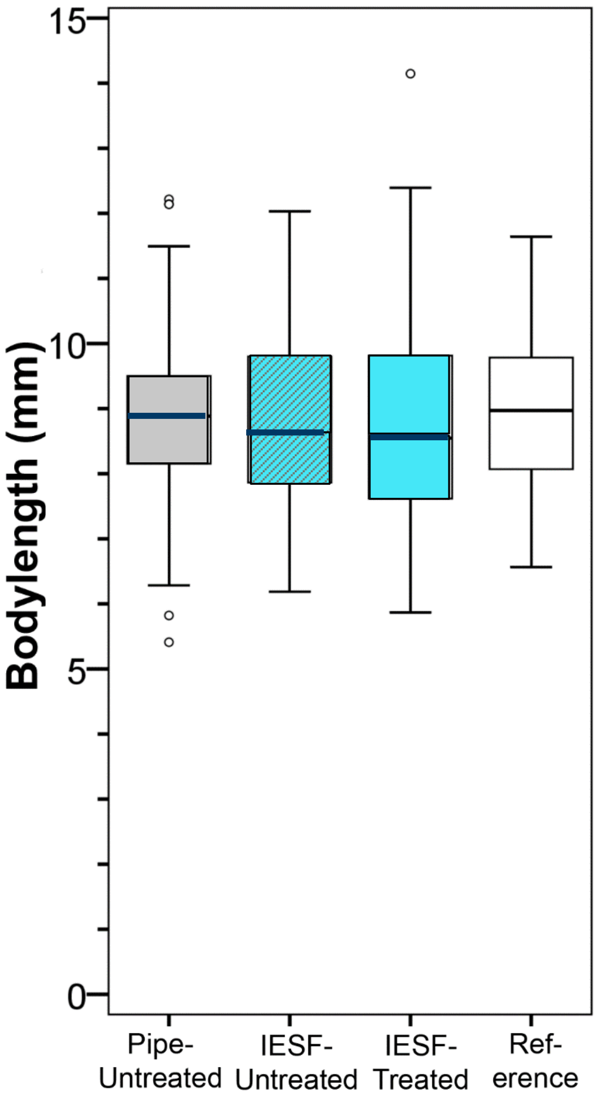


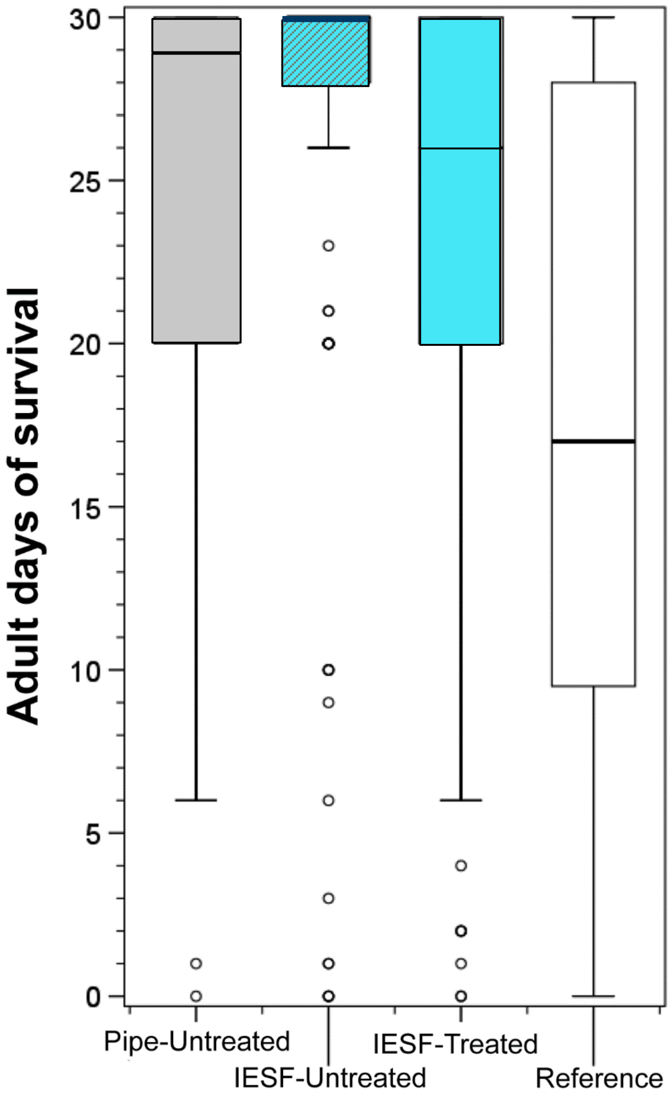
Stats Codes: *: IESF-Out < IESF-In
#: IESF-Out < Pipe but not IESF-In

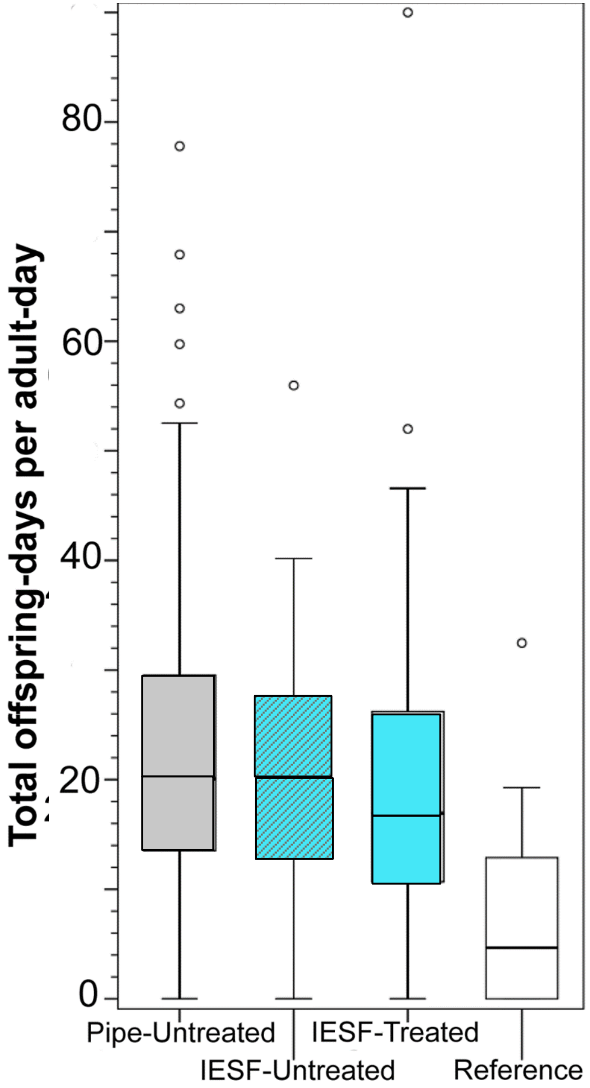
Bioassay Results By Site Type

Stormwater Outfall | IESF-In | IESF-Out | Reference









Next Steps

- **Journal articles in review for CECs and daphnia/fathead minnow bioassays**
  - *Water Research* (CECs) & *Environmental Science & Technology* (bioassays)
  - RNA-omics & *in vitro* bioassay manuscript in development
- **IESF dataset completion & analysis**
  - Hydrology & watershed parameters
  - Multivariate analysis
  - Characterize IESF performance in terms of loads, concentrations, and their influences
  - Include additional available IESF monitoring data from other MN sites
  - Develop MPCA report, MN Stormwater Manual content, research article
  - Update MPCA guidance
- **And onward & upward..**

Acknowledgements

- **IESF Project Partners**
  - City of Minneapolis & Minneapolis Board of Parks & Recreation
  - Ramsey Washington Metropolitan Watershed District
  - City of Prior Lake
  - Capitol Region Watershed District & City of St. Paul
  - St. Cloud State University
  - USGS – Mounds View office
  - University of St. Thomas
  - MPCA & MPCA staff partners
- **State of Minnesota: Clean Water, Land, and Legacy Fund**
- **Local funding sources through project partners**
- **Many others**

Selected References

- **County, K., 1998.** Lake Sammamish Water Quality Management Project, Final Report. *King County Department of Natural Resources, Seattle, WA*.

- **Erickson AJ, Gulliver JS, Weiss PT. 2012.** Capturing phosphates with iron enhanced sand filtration. Water Res 46:3032-3042.

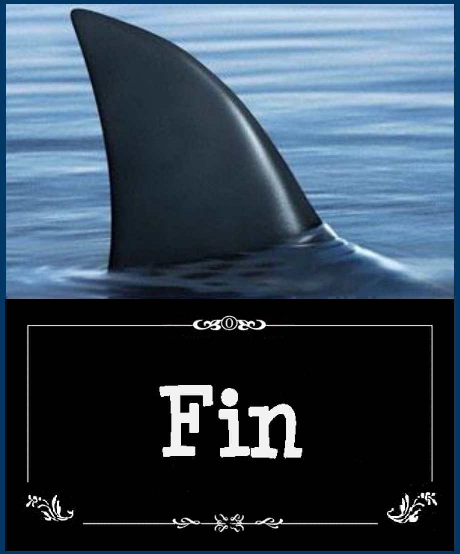
- **Erickson AJ, Gulliver JS, Weiss PT. 2015**. Monitoring an Iron-Enhanced Sand Filter Trench for the Capture of Phosphate from Stormwater Runoff. MPDI Water 9(672):1-17.

- **Minneapolis Parks & Recreation Board. 2015.** 2015 Water Resources Report. URL: https://www.minneapolisparks.org/_asset/0jd11p/water_resources_report_2015.pdf

- **Minnesota Stormwater Manual Contributors, 2018.** Minnesota Stormwater Manual. URL: https://stormwater.pca.state.mn.us/index.php?title=Main_Page

Questions?

CLEAN WATER LAND & LEGACY AMENDMENT



David Fairbairn

david.fairbairn@state.mn.us

651-757-2659

MINNESOTA POLLUTION CONTROL AGENCY